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Scientific Basis To Establish Policy Regulating Communications Towers To Protect Migratory Birds: Response to Avatar Environmental, LLC, Report Regarding Migratory Bird Collisions With Communications Towers, WT Docket No. 03-187, Federal Communications Commission Notice of Inquiry

Prepared for:

American Bird Conservancy
Defenders of Wildlife
Forest Conservation Council
The Humane Society of the United States

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1. Introduction

On December 14, 2004, the Federal Communications Commission ("FCC") made available a review of comments received for its Notice of Inquiry on Avian/Communication Tower Collisions. The Notice of Inquiry was issued on August 20, 2003 and closed on December 6, 2003. A team of consultants (Avatar Environmental, LLC, EDM International, Inc., and Pandion Systems, Inc.) was retained by the FCC in May 2004 and reviewed all of the comments received. Their report, "Notice of Inquiry Comment Review Avian/Communication Tower Collisions" ("Avatar Report"), dated September 30, 2004, includes recommendations of actions that might be taken by the FCC.

Land Protection Partners was engaged by the American Bird Conservancy, Forest Conservation Council, Defenders of Wildlife, and The Humane Society of the United States to provide an analysis of the conclusions and recommendations of the Avatar Report, and to provide the scientific basis, if any, for regulating communications towers to protect birds. We have found that the conclusions of the Avatar Report do not adequately represent the current state of scientific knowledge about bird kills at communications towers in many important respects, and that the recommendations derived from those conclusions are insufficient to address the adverse impacts of communications towers on birds.

This report is based on a review of the published scientific literature (both studies discussed in the Avatar Report and others), a peer-reviewed study now in press,[1] progress reports of a scientific study now in progress,[2] and personal communications with scientists working in this field. We first consider the question of whether bird kills at communications towers are biologically significant. We then address various factors that influence the number and rate of bird kills at towers: tower height, tower configuration, tower lighting, and local topography. Although weather influences bird kills at towers, it is not discussed in detail here because it cannot be regulated.

All parties involved in the debate over tower kill acknowledge that birds are killed in some number at towers. The Avatar Report documents this and finds that, "Overall, there is general agreement that there is sufficient documented evidence of avian mortality by communications towers and that the construction and operation of tall structures will

1. Gauthreaux, S.A., Jr., and C. Belser. 2005. Effects of artificial night lighting on migrating birds. *In* C. Rich and T. Longcore (eds.), *Ecological consequences of artificial night lighting*. Island Press, Covelo, California.
2. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant.

likely result in the risk of bird collisions and possible mortalities,”[3] and, “That birds are colliding with towers has been well documented.”[4] The Avatar Report further cites several sources estimating that mortality is between 2 million to 5 million birds per year, but ignores a letter to the FCC Chairman from the Director of the U.S. Fish and Wildlife Service dated November 2, 1999, where the Director references data indicating that the number of migratory birds killed by communications towers may be 4 million per year to an order of magnitude above this (40 million per year).

Assessment of the cumulative significance of tower-caused avian mortality is confounded by the absence of monitoring at a large number of towers. Because the FCC does not require monitoring at towers that it registers or otherwise approves, and because tower operators do not conduct such monitoring, bird kills reported in the literature represent only a minimum measurement of the total mortality. The majority of tower sites are never checked for mortality and even those that are checked are done so only on a sporadic basis. In addition, the reported numbers are based on actual carcasses found and there is no extrapolation for predator/scavenger removal or search efficiency. This means, as the Avatar Report notes, that the numbers of birds killed are higher than reported. Two of the longer-term studies with periodic searches confirm that numbers of birds killed can be significant at one tower: a 38-year study of a single 1,000-foot television tower in west central Wisconsin documented 121,560 birds killed representing 123 species,[5] and a 29-year study at a Florida television tower documented the killing of more than 44,000 birds of 186 species.[6] Neither of these studies adjusted carcass counts upward to account for search efficiency and predator/scavenger removal.

We do know that communications towers kill millions of birds annually, and that a very high percentage of these are neotropical migratory birds that migrate at night.[7]

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3. Avatar Report, p. 3-19.
4. Avatar Report, p. 3-20.
5. Kemper, C.A. 1996. A study of bird mortality at a central Wisconsin TV tower from 1957–1995. *Passenger Pigeon* 58:219–235.
6. Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
7. See Shire, G.G., K. Brown, and G. Winegrad. 2000. *Communication towers: a deadly hazard to birds*. American Bird Conservancy, Washington, D.C. Banks R.C. 1979. Human related mortality of birds in the United States. *U.S. Fish and Wildlife Service, Special Scientific Report – Wildlife* 215:1–16. Clark, J.R. 14 September 2000. Service guidance on the siting, construction, operation and decommissioning of communications towers. U.S. Fish and Wildlife Service, Washington, D.C. Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, Jr., K.J. Sernka, and R.E. Good. 2001. *Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States*. National Wind Coordinating Committee (NWCC) Resource Document. Woodlot Alternatives. 2003. An assessment of factors associated with avian mortality at communications towers — a review of existing scientific literature and incidental observations. Topsham, Maine (“Woodlot Report”).

2. Kills of Birds at Communications Towers Can Be Biologically Significant

Scientists do not have an accepted definition of "biological significance," and, in fact, do not use the term in any regular fashion. The terms "significant" and "significance" are generally reserved for the description of statistical results. To be useful to a scientist, "biological significance" must be defined in terms that can be measured. The Avatar Report states that, "biologically significant mortality is any mortality that is of sufficient magnitude and importance that it causes the viability of a particular population or species to be affected."[8] Elsewhere, the Avatar Report states that, "declines of local, regional, or range-wide populations [of species] would be biologically important,"[9] and presumably "significant." It is important to note that the Avatar Report provides no statutory basis for establishing this standard, nor does it attempt to apply this standard to any of the avian species or populations that are killed by towers.

It is apparent from the comments submitted in response to the Notice of Inquiry, especially those by the communications industry, that the standard for significance at issue is not a scientific standard, but rather a statutory standard under the National Environmental Policy Act ("NEPA").[10] For purposes of this report, we assume that "biologically significant" means a significant impact to biological resources under NEPA.

The Avatar Report does not outline the standards used by the FCC to determine significance of impacts to biological resources under NEPA.[11] The report does assert, however, that analysis of biological significance would be possible for well-studied bird populations such as Kirtland's Warbler and Red-cockaded Woodpecker, but then does not conduct any analysis or provide any insight into whether tower kill would be "biologically significant" for these species.

The communications industry likewise fails to present a coherent analysis of biological significance.[12] The industry relies on an argument that bird kills at communications towers are so small relative to other forms of human-caused bird mortality that they are insignificant by definition.[13] Because this argument is repeated (without critical analysis) in the Avatar Report, it deserves special consideration.

The communications industry bases its conclusions about the "significance" of bird kills at towers on the report prepared by Woodlot Alternatives ("Woodlot Report"). In this report, Woodlot Alternatives attempts to tabulate all of the sources of human-caused mortality for birds. From these rough estimates, Woodlot Alternatives concludes that

8. Avatar Report, p. 3-66.
9. Avatar Report, p. 3-62.
10. Cellular Telecommunications & Internet Association and National Association of Broadcasters. 2003. Comments of the Cellular Telecommunications & Internet Association and National Association of Broadcasters in the matter of effects of communications towers on migratory birds, WT Docket No. 03-187 ("CTIA/NAB Comments"), p. 11.
11. Avatar Report, p. 3-67.
12. See CTIA/NAB Comments and Woodlot Report.
13. CTIA/NAB Comments and Woodlot Report.

tower kill constitutes only 0.5% of the human-caused mortality of birds. This approach is inappropriate to any discussion of "biological significance" because it refers to mortality for **all** birds, not for any particular bird species or population of birds. The different human-induced causes of mortality do not affect all birds equally; any given type of mortality is more important for some species and less important for others. Generally speaking, as an example, birds that are subjected to oil spills are not also vulnerable to predation by house cats. Expressing tower kill mortality as a percentage of total human-induced mortality therefore does not make sense. Even if it were a rational approach, it is interesting to note that consultants for the wind industry undertook a similar analysis and concluded that communications towers result in 1–2% of human-caused mortality (not 0.5%).[14]

The estimates of total human-caused bird mortality are not relevant to determine whether kills at communications towers meet the NEPA standard for a significant impact. The FCC checklist for environmental impacts requires disclosure of placement of towers in wilderness or designated wildlife refuges, and disclosure of any potential impacts to species that are candidate species or listed under the Endangered Species Act. These FCC guidelines omit elements of NEPA analysis that are routine in other circumstances, including violation of the Migratory Bird Treaty Act, which prohibits the killing of any migratory bird, even unintentionally, without a permit. It is also customary to consider the impacts of a project to be significant if those impacts: 1) reduce populations of species of local conservation significance, such as those listed under state endangered species acts, 2) interrupt the movement of wildlife across the landscape, or 3) result in declines in species that will lead to their endangerment.

The available data are sufficient to allow an estimation of the number of individuals killed at towers on a species-by-species basis, which is a necessary approach to assess impacts to biological resources in any situation. Such an analysis is essential because whatever threshold of significance is applied, it will be applied to species, not to "birds" as a whole.

2.1. Estimate of Numbers of Birds Killed at Tower by Species

To estimate the number of individuals of each species killed at towers, we used species lists of birds killed at towers to determine the percentage representation of each species, which we multiplied by estimates of total birds killed per year at towers. The number of individuals of each species killed was collated by the American Bird Conservancy from 47 studies with complete lists of birds killed at communications towers.[15] The 47 studies were from 31 states and two Canadian provinces east of the Rocky Mountains, and report deaths of 184,797 birds at communications towers. We assume that the proportion of

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14. Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, Jr., K.J. Sernka, and R.E. Good. 2001. *Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States*. National Wind Coordinating Committee (NWCC) Resource Document, p. 16.
15. Shire, G.G., K. Brown, and G. Winegrad. 2000. *Communication towers: a deadly hazard to birds*. American Bird Conservancy, Washington, D.C.

each species in this dataset equals the proportion of individuals of the species killed each year at towers. We multiplied the percentage of each bird species in the dataset by a low (4 million) and high (40 million) estimate of total bird mortality at communications towers to obtain a range of the number of each species killed each year. Because the range of total number of birds killed per year is large, even at the lower end of estimates, it does not matter substantially if the actual percentage of each bird species killed per year is slightly different from our assumption. For example, whether Ovenbirds represent 10% or 12% of all kills is not particularly consequential; even the lower percentage represents a large number of individuals killed per year. This methodology provides a range of magnitude estimate for each species killed at towers.

The results show that for the ten avian species killed most frequently at towers, total annual mortality is estimated to be from 490,000 to 4.9 million **for each species**.

Table 1. Estimates of total number of birds killed per species by communications towers each year. Includes top ten bird species killed and all birds of conservation concern (BCC) identified by the U.S. Fish and Wildlife Service.[16]

Species	Total Killed	Percentage Killed	Number killed per year (low)	Number killed per year (high)
Top Ten Birds Killed				
Ovenbird	22,619	12.240%	489,597	4,895,967
Red-eyed Vireo	19,707	10.644%	426,565	4,265,654
Tennessee Warbler	17,689	9.572%	382,885	3,828,850
Common Yellowthroat[17]	10,397	5.626%	225,047	2,250,469
Bay-breasted Warbler (BCC)	10,396	5.626%	225,025	2,250,253
American Redstart	8,392	4.541%	181,648	1,816,480
Blackpoll Warbler (BCC)	6,304	3.411%	136,452	1,364,524
Black-and-white Warbler	6,099	3.300%	132,015	1,320,151
Philadelphia Vireo	4,317	2.336%	93,443	934,431
Swainson's Thrush	3,943	2.134%	85,348	853,477
Birds of Conservation Concern Below Top Ten				
Northern Waterthrush	3,148	1.703%	68,140	681,396
Northern Parula	2,662	1.440%	57,620	576,200
Connecticut Warbler	2,624	1.420%	56,797	567,975
Cape May Warbler	2,119	1.190%	47,598	475,982
Black-throated Blue Warbler	2,061	1.115%	44,611	446,111
Chestnut-sided Warbler	1,426	0.772%	30,866	308,663

16. U.S. Fish and Wildlife Service. 2002. Birds of conservation concern 2002. Division of Migratory Bird Management, Arlington, Virginia. The U.S. Fish and Wildlife Service's Birds of Management Concern List is a statutorily required listing of avian species that may become candidates for listing under the Endangered Species Act without additional conservation action and for which special attention is warranted to prevent declines. Congress dictated such a list be prepared at least every five years as an early warning system to try to prevent birds from becoming listed under the Endangered Species Act.
17. Subspecies *sinuousa* is of conservation concern.

Species	Total Killed	Percentage Killed	Number killed per year (low)	Number killed per year (high)
Black-throated Green Warbler	1,330	0.720%	28,788	287,883
Bobolink	1,201	0.650%	25,996	259,961
Prairie Warbler	1,018	0.551%	22,035	220,350
Marsh Wren	888	0.481%	19,221	192,211
Canada Warbler	689	0.373%	14,914	149,137
Wood Thrush	684	0.370%	14,805	148,054
Grasshopper Sparrow	582	0.315%	12,598	125,976
Yellow-billed Cuckoo	568	0.307%	12,295	122,946
Kentucky Warbler	568	0.307%	12,295	122,946
Golden-winged Warbler	542	0.293%	11,732	117,318
Prothonotary Warbler	476	0.258%	10,303	103,032
Yellow Warbler[18]	419	0.227%	9,069	90,694
Yellow-throated Warbler	339	0.183%	7,338	73,378
Swainson's Warbler	336	0.182%	7,273	72,728
Worm-eating Warbler	255	0.138%	5,520	55,196
Yellow-bellied Sapsucker	228	0.123%	4,935	49,351
Dickcissel	171	0.093%	3,701	37,014
Cerulean Warbler	164	0.089%	3,550	35,498
Field Sparrow	147	0.080%	3,182	31,819
Acadian Flycatcher	134	0.073%	2,900	29,005
Sedge Wren	107	0.058%	2,316	23,161
Louisiana Waterthrush	103	0.056%	2,229	22,295
Blue-winged Warbler	83	0.045%	1,797	17,966
Orchard Oriole	79	0.043%	1,710	17,100
Bachman's Sparrow	74	0.040%	1,602	16,018
Yellow Rail	67	0.036%	1,450	14,502
Sharp-tailed Sparrow spp.	51	0.028%	1,104	11,039
Henslow's Sparrow	49	0.027%	1,061	10,606
Le Conte's Sparrow	36	0.019%	779	7,792
Red-headed Woodpecker	33	0.018%	714	7,143
American Bittern	32	0.017%	693	6,927
Alder Flycatcher	25	0.014%	541	5,411
Rusty Blackbird	12	0.006%	260	2,597
Seaside Sparrow	12	0.006%	260	2,597
Black Rail	8	0.004%	173	1,732
Common Ground Dove	8	0.004%	173	1,732
Harris's Sparrow	8	0.004%	173	1,732
Whip-poor-will	7	0.004%	152	1,515
Chuck-will's Widow	6	0.003%	130	1,299

18. Only resident subspecies *gundlachi* is of conservation concern.

Species	Total Killed	Percentage Killed	Number killed per year (low)	Number killed per year (high)
Painted Bunting	6	0.003%	130	1,299
Bell's Vireo	4	0.002%	87	866
Little Blue Heron	4	0.002%	87	866
Olive-sided Flycatcher	4	0.002%	87	866
Solitary Sandpiper	4	0.002%	87	866
Bewick's Wren	3	0.002%	65	649
Loggerhead Shrike	2	0.001%	43	433
Red-cockaded Woodpecker[19]	2	0.001%	43	433
Upland Sandpiper	2	0.001%	43	433
Baird's Sparrow	1	0.001%	22	216
Black-capped Petrel	1	0.001%	22	216
Common Tern	1	0.001%	22	216
Franklin's Gull	1	0.001%	22	216
McCown's Longspur	1	0.001%	22	216
Northern Harrier	1	0.001%	22	216
Semipalmated Sandpiper	1	0.001%	22	216
Smith's Longspur	1	0.001%	22	216
White Ibis	1	0.001%	22	216
Willet	1	0.001%	22	216

The results of this analysis show the range of mortality per year experienced by bird populations from communications towers alone, assuming that overall mortality at towers is between 4 and 40 million individuals per year. But even if total mortality at towers is 2 million individuals per year, the most frequently killed bird species will lose 250,000 individuals per year, and a single record of a death at a tower in any of the 47 studies with complete lists can be extrapolated to approximately 10 birds per year for that species. With the worst-case scenarios (40 million birds per year killed), the top ten most commonly killed birds would suffer losses of ~1 million to ~4 million individuals per year, including two species of conservation concern (Bay-breasted Warbler and Blackpoll Warbler).[20] Even without going further, we note that the killing of 1 million to 2 million or even 100,000–200,000 individuals of a bird species of regulatory concern annually typically would be considered a significant impact in environmental impact analysis. To further illustrate the potential significance of these levels of mortality, we consider the population dynamics of neotropical migrants, which are most affected by collisions with communications towers.

19. Listed under Endangered Species Act.
20. U.S. Fish and Wildlife Service. 2002. Birds of conservation concern 2002. Division of Migratory Bird Management, Arlington, Virginia.

2.2. Highest Mortality for Neotropical Migrants Currently Occurs During Migration

The migratory period has been suspected to be the "critical period contributing to long-term declines in some species."[21] To address this question, Sillett and Holmes presented a long-term study of Black-throated Blue Warbler, which is documented as being killed at communications towers (1.15% of all records) and is a federal species of conservation concern, based on observations at breeding grounds in New Hampshire and wintering grounds in Jamaica.[22] They found that survival of individuals was high during the summer (0.99 ± 0.01) and winter (0.93 ± 0.05), while survival during both spring and fall migration ranged only 0.67–0.73. This was the first quantification of migration mortality for a neotropical migrant, and the results reinforced concern about the migratory period as playing an important role in species declines. These survival estimates mean that apparent mortality rates during migration were 15 times greater than during breeding and wintering seasons, and that over 85% of total mortality occurred during migration. Sillett and Holmes conclude that both habitat conditions before migration and conditions during migration affect mortality.

> Consequently, migrant populations could be especially susceptible to processes that further reduce survival of individuals during migration, such as destruction of high-quality winter habitats and stopover sites, and increases in the number of communications towers along migration routes.[23]

While it is premature to conclude that the majority of mortality for all neotropical migrants occurs during migration, it is the case for at least one species. Extra mortality, such as the 45,000–450,000 individuals per year of Black-throated Blue Warbler killed at towers, during a period that is already stressful likely contributes to recorded regional population declines or even overall population declines for the federal species of conservation concern.

2.3. Tower Kills Could Contribute to Population Declines in Neotropical Migrants

Additional mortality during migration could affect population trends for songbirds. It is unlikely that tower kill is compensatory. If birds that would die anyway were the only ones killed at towers (i.e., compensatory mortality), then they should show common characteristics that distinguish them from others, such as being young, old, below average weight, or disproportionately of one sex. Studies of Ovenbirds killed at towers do not

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21. Hutto, R.K. 2000. On the importance of *en route* periods to the conservation of migratory landbirds. *Studies in Avian Biology* 20:109–114.
22. Sillett, T.S., and R.T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. *Journal of Animal Ecology* 71:296–308.
23. Sillett, T.S., and R.T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. *Journal of Animal Ecology* 71:296–308, p. 305.

reveal a consistent pattern of a particular age, sex, or weight of bird being killed,[24] which we take to be evidence against tower kills being compensatory mortality. If this is true, then birds killed at towers represent a chronic, additive drain on populations and will affect population size. To assess whether this effect is "biologically significant," we compared the estimated mortality for selected species with the Partners In Flight conservation targets for various regions in the eastern United States (Table 2). Partners In Flight is a collaborative effort for bird conservation that includes many government and non-profit stakeholders, and its scientific assessment of threats to birds is used as part of the U.S. Fish and Wildlife Service's determination of "birds of conservation concern." These goals are expressed by Bird Conservation Region (BCR).

Table 2. Comparison of selected bird conservation goals by Bird Conservation Region (BCR) from Partners In Flight with estimated annual tower kill *per year*. Conservation goals converted from pairs to individuals by doubling number of pairs.

BCR	Species	Regional Conservation Goal	Estimated Tower Kill Per Year
Adirondacks	Canada Warbler	30,000–40,000	15,000–150,000
Adirondacks	Black-throated Blue Warbler	100,000–110,000	44,000–440,000
Adirondacks	Golden-winged Warbler	2,000	12,000–120,000
Mid-Atlantic Piedmont	Grasshopper Sparrow	70,000	13,000–130,000
Mid-Atlantic Ridge and Valley	Wood Thrush	700,000	15,000–150,000
Lower Great Lakes Plain	Upland Sandpiper	1,200	40–400
Ohio Hills	Cerulean Warbler	300,000	3,500–35,000
Northern Ridge and Valley	Worm-eating Warbler	36,000	5,500–55,000
Northern Ridge and Valley	Louisiana Waterthrush	18,000	2,000–20,000
Northern Ridge and Valley	Bobolink	24,000	26,000–260,000
Mid-Atlantic Coastal Plain	Prothonotary Warbler	32,000	10,000–100,000

Even with the most conservative estimates of bird mortality at communications towers, it is evident that the number of birds of certain species killed each year can be as great as

24. Taylor, W.K. 1972. Analysis of Ovenbirds killed in central Florida. *Bird-Banding* 43:15–19. Brewer, R., and J.A. Ellis. 1958. An analysis of migrating birds killed at a television tower in east-central Illinois, September 1955–May 1957. *Auk* 75:400–414. Eaton, S.W. 1967. Recent tower kills in upstate New York. *Kingbird* 17:142–146. Goodpasture, K.A. 1963. Age and sex determinations of tower casualties, Nashville, 1963. *Migrant* 34:67–70. Johnston, D.W., and T.P. Haines. 1957. Analysis of mass bird mortality in October, 1954. *Auk* 74:447–458. Tordoff, H.B., and R.M. Mengel. 1956. Studies of birds killed in nocturnal migration. *University of Kansas Publications, Museum of Natural History* 10:1–44.

the conservation goal for those species for whole regions. By any rational standard of environmental impact analysis, this constitutes a significant impact to biological resources. Even if bird mortality at communications towers is half of the lowest estimate (i.e., 2 million per year), the effects would still be significant.

Discovery of any one specimen of an endangered species at a communications tower would be an indicator of a significant impact on the population of the species. If just one Kirtland's Warbler had been part of the dataset that we analyzed in Table 1, then the interpretation would be that between approximately 20 and 200 individuals of this species are killed at communications towers each year. The total population size of Kirtland's Warbler is only ~2,000 breeding individuals each year. Each breeding pair produces on average 2.2 fledglings,[25] meaning that approximately 4,200 birds migrate each year. If our extrapolation is close, then communications towers would kill between 0.5% and 5% of the migrants of this species each year. That Kirtland's Warblers are not regularly found at communications towers is evidence only of the rarity of the species and the low total effort put into searching for birds around the thousands of towers in its migratory pathway, not that Kirtland's Warblers are avoiding communications towers.

Although not a neotropical migrant, population effects from tower mortality could affect viability of Red-Cockaded Woodpecker. Based on two recovered carcasses, the extrapolated mortality rate of ~40–400 Red-cockaded Woodpeckers annually would represent 0.4–4% of the total population of ~11,000 birds.[26]

The Avatar Report acknowledges that tower kills may have significant impacts on threatened or endangered species, but the authors of the report did not conduct any analysis.[27] Our analysis illustrates that not only are impacts possible, they are foreseeable and likely and therefore require analysis under NEPA.

Our analysis does, however, carry a caveat. These examples illustrate only that it is likely and foreseeable that bird mortality at towers has a significant impact on populations of birds; they are not meant to be precise predications of mortality from communications towers. These results will change as estimates of the total bird mortality at towers are refined. They do show, based on current knowledge, the range of magnitude that tower mortality has on individual species, rather than lumping all bird mortality into one number, as is done in the Avatar Report.

We conclude that the magnitude of mortality of individual species of birds at communications towers constitutes a significant impact, alone and cumulatively, within the under-

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25. Mayfield, H.F. 1992. Kirtland's Warbler (*Dendroica kirtlandii*). Pp. 1–16 *in* A. Poole, P. Stettenheim, and F. Gill (eds.), *The Birds of North America*, Vol. 19. Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologist's Union.
26. Jackson, J.A. 1994. Red-cockaded Woodpecker (*Picoides borealis*). Pp. 1–20 *in* A. Poole and F. Gill (eds.), *The Birds of North America*, Vol. 85. Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologist's Union.
27. Avatar Report, p. 5-2.

standing of NEPA. Beside the biological impact, this is a profound loss for the roughly 46 million Americans who watch and enjoy birds in their local environments.[28] Declines of migratory birds, from backyard species, to less common migrants, to rare and endangered species, diminish the human environment, and this should be recognized within the NEPA process as well.

3. Tower Height Affects Bird Mortality Rate

The Avatar Report reaches the conclusion that, "All other things being equal, taller towers with lights tend to represent more of a hazard to birds than shorter, unlit towers."[29] While true, this statement is too general to be useful, and no recommendation is made to regulate the height of new towers. Rather, the Avatar Report simply reviews the comments submitted. Perhaps this was the intention of the FCC, but it would seem that this would be the opportunity to analyze statistically the relationship between tower height and bird kills. The comments submitted by industry representatives to the FCC contain only a general description of the relationship between the size of bird kills, annual rate of bird kills, and tower height. Woodlot Alternatives, representing the communications industry, concludes, "There is little evidence of a threshold of tower height that is more dangerous to birds."[30] This statement is not consistent with the available evidence as we document below.

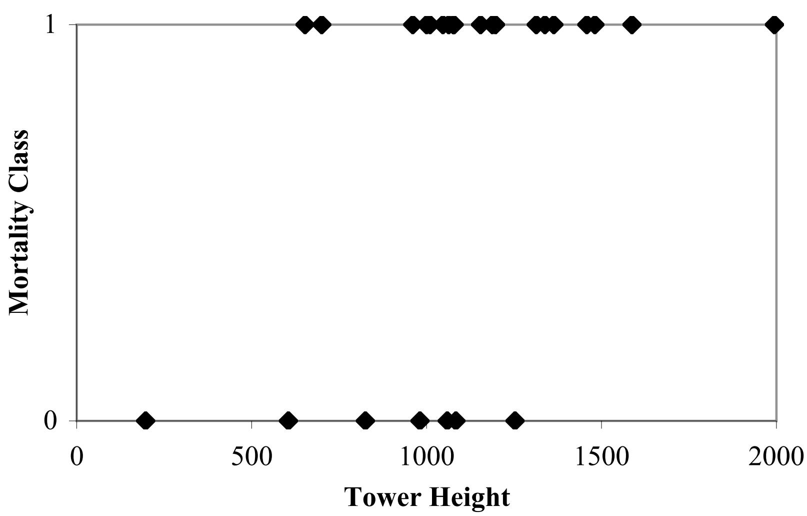

Figure 1. Mortality class by tower height for long-term tower kill studies. The mortality classes are below 250 birds per year (0) and above 250 birds per year (1). See Section 10 for raw data.

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28. U.S. Fish and Wildlife Service. 2002. 2001 National survey of fishing, hunting, and wildlife-associated recreation: national overview. U.S. Fish and Wildlife Service, Washington D.C. United States Fish and Wildlife Service. 2001. Birding in the United States: a demographic and economic analysis, report 2001-1. U.S. Fish and Wildlife Service, Washington D.C.
29. Avatar Report, p. 5-1.
30. Woodlot Report, p. 25.

3.1. Long-term Studies Show Effect of Tower Height on Bird Mortality

To investigate the relationship between tower height and bird mortality, we conducted a meta-analysis of studies of bird kills at towers that provide or allow estimates of annual mortality and include the height of the tower studied. Many of these studies are summarized in existing reports, such as the Woodlot Report. The mean annual mortality was reported for each study from the underlying article, or calculated by others. We classified each tower as causing mean annual mortality either less than 250 birds per year or more than 250 birds per year as an indicator of the magnitude of the annual kill (Figure 1). This threshold represents the bottom quartile of the number of annual kills. This conversion of a continuous variable (mean annual mortality) to a nominal variable reduces the effect of different study methodologies, search efficiencies, and scavenger removal. We then completed a logistic regression on mortality class with tower height as the independent variable (Figure 2). The data used in this analysis are included at the end of this report.

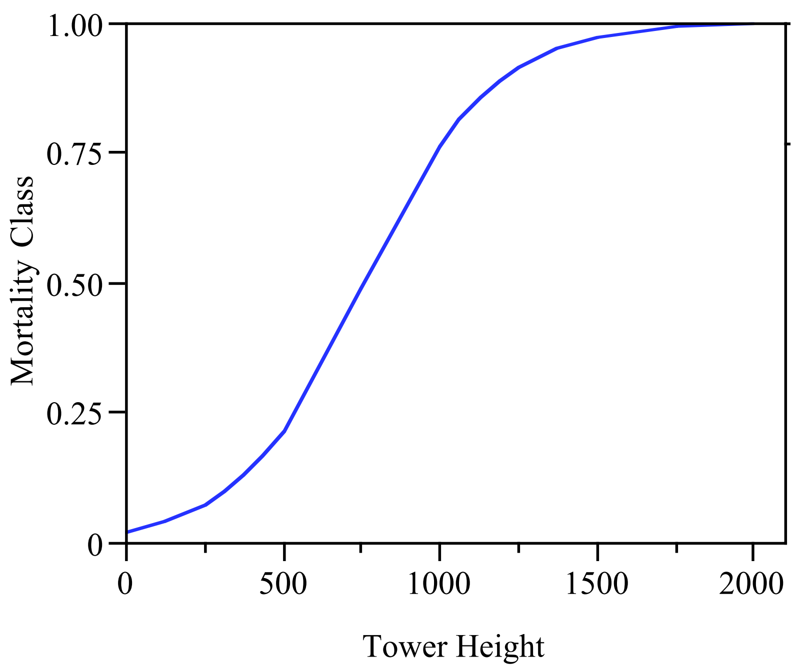

Figure 2. Logistic regression of birds killed per year by mortality class over or under 250 birds (lowest quartile or upper three quartiles) by tower height ($r^2 = 0.27$, $P < 0.01$). Line indicates probability of annual mortality falling over or under 250 birds per year. See Section 10 for source data.

The 26 towers that make up the data points for this regression are located in 14 states, with one to seven per state. When multiple studies were conducted on a given tower, only a single study was used to avoid double-counting. The regression is significant ($r^2 = 0.27$, $P < 0.01$).

The logistic regression provides a model that relates tower height with annual bird mortality. Because the data used to develop this model are all from towers that have recorded bird kills, the results cannot be extrapolated to all towers. For towers that cause bird kills, tower height is a strong predictor of whether the annual number of deaths is in the lowest quartile. In addition to providing a statistically significant description of the effect of tower height on bird mortality, the model can be used to predict the tower height necessary for bird kills to be below 250 per year a given percentage of the time. This model predicts that only 5% of the time would towers less than 160 feet tall cause more than 250 casualties per year, and only 25% of the time would towers less than 536 feet cause more than 250 casualties per year.

The effects of height are amplified by lighting at towers, so the lower mortality at shorter towers that do not require lighting, such as the one 197-foot tower in the analysis, is likely to be partly attributable to the lack of lighting. It is impossible, however, to investigate the effects of height completely independent of lighting, because all towers over 200 feet require some form of FAA-approved obstruction lighting. To ensure that our results were not biased by the inclusion of the one unlighted tower, we performed a logistic regression without this data point and still obtained a significant relationship between tower height and mortality class ($r^2 = 0.18$; $P < 0.05$) with all of the lighted towers.

More long-term studies of towers shorter than 500 feet would improve this model, but the model is certainly adequate to begin to make policy recommendations. Following this model, it would drastically reduce bird mortality to keep as many towers as possible below 199 feet, which both avoids FAA-required lighting (see below) and, according to our analysis, would avoid large yearly kills 90–95% of the time.

3.2. Statewide Study in Michigan With Random Sampling Design Shows Significant Effect of Tower Height on Bird Mortality

The results of our re-analysis of existing records of annual mortality rates at towers can only be extrapolated to towers that are known to kill birds (the towers analyzed were studied because they killed birds and not selected randomly) and share other characteristics (all towers were guyed and all but one was lighted). The results of our meta-analysis are consistent with an ongoing study with a random sampling design that compares mortality at different tower types. This research, led by Dr. J. Gehring of Central Michigan University, compares bird mortality rates at short unguyed towers, short guyed towers, and tall guyed towers (Figure 3). Differences between guyed and unguyed towers are discussed below. Bird mortality at 380–480 foot towers was significantly less than mortality at taller (1,000 foot) towers. On average, the taller towers killed over four times more birds during 20-day spring and fall survey seasons than did 380–480 foot towers. These towers were not known to be susceptible to bird collisions prior to the study. Adjustments were made for search efficiency and scavenger removal, but these did not change the character of the raw results. Because of the randomized study design, the results from the Gehring study are powerful new evidence of the role of height in bird mortality.[31]

The Gehring study has not yet detected any mass kill of birds, which is to be expected because the size of kills is inversely proportional to their frequency. The study provides evidence of the effects of height on chronic bird collisions with lighted, guyed towers. Lighting type may have influenced these results somewhat; the towers were lighted with solid red and flashing red lights but the flashing lights were of the strobe type on the 380–480 foot towers, and incandescent on the taller towers. Strobe-type lights extinguish completely between flashes while incandescent lights dim slowly. Darkness between flashes is thought to be important in reducing bird attraction. But both tower heights had solid red lights, which are more attractive to birds than either flashing light type.

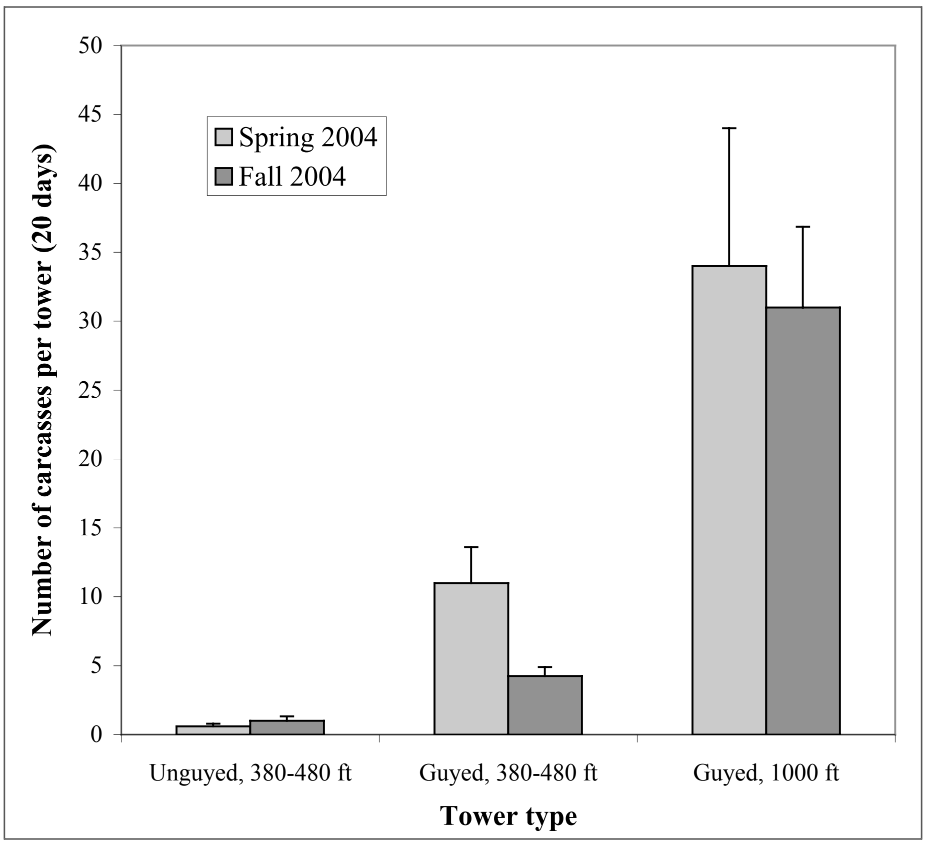

Figure 3. Bird carcasses found at towers in Michigan.[32] All towers were lit with combinations of solid red (L-810) and flashing red lights (L-864; strobe type on shorter towers, incandescent on taller towers). Error bars indicate standard error.

31. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant.

With these results being consistent with the analysis of annual mortality presented above, it is possible to identify thresholds for the effects of tower height on bird mortality. From the logistic model above, that threshold for guyed towers is approximately 160 feet to keep mean annual mortality below 250 birds per year 95% of the time. There is no single tower height threshold that will eliminate bird collisions entirely, except zero feet. But the number of birds killed can be minimized by reducing tower heights and this reduction appears from the data to be quite drastic between 1,000 feet and 500 feet. There are certainly examples of towers of the same height killing different numbers of birds[33] and of shorter towers, even as short as 100 feet, killing birds under certain circumstances, but this variation in the data does not disprove the relationship.

The results of our analysis are consistent with the Gehring study with random sampling design and with surveys of bird kills after taller towers have been replaced with shorter towers. Crawford and Engstrom report decreased mortality following the reduction of a 1,008-foot tower to 284 feet.[34] Furthermore, in instances where a taller tower has been erected next to a shorter tower, more birds are killed at the shorter tower than before,[35] presumably because of the attracting effect of lights on the taller tower. Finally, the statistically significant relationship between tower height and bird mortality is consistent with studies of the vertical distribution of nocturnal migrants measured with radar. Most migrants fly at ~1,500 feet,[36] with a small proportion (2–15% in one study[37]) below 300 feet during clear weather. Greater proportions of total migrants (26–46%, depending on the season and location) are found in the strata up to ~1,300 feet, although the strength of radar used in that study[38] may underestimate the number of birds at higher altitude. All other things being equal, substantially more birds will encounter taller towers (greater than 300 feet) and their guy wires than shorter towers (less than 300 feet).

The logistic regression analysis of annual mortality and the Gehring study fully substantiate the U.S. Fish and Wildlife Service tower siting guidelines to better protect birds:

1. Any company/applicant/licensee proposing to construct a new communica-

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32. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant.
33. Woodlot Report, p. 26.
34. Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
35. Stoddard, H.L., Sr., and R.A. Norris. 1967. Bird casualties at a Leon County, Florida TV tower: an eleven-year study. *Bulletin of Tall Timbers Research Station* 8:1–104. Wiseman, J. 1975. TV tower kills – Barrie (Ontario). *Blue Heron* 19:5. Hoskin, J. casualties at the CKVR-TV tower, Barrie. *Nature Canada* 4:39–40.
36. Able, K.P. 1970. A radar study of the attitude of nocturnal passerine migration. *Bird-Banding* 41(4):282–290. Bellrose, F.C. 1971. The distribution of nocturnal migrants in the air space. *Auk* 88:387–424.
37. Mabee, T.J., and B.A. Cooper. 2004. Nocturnal bird migration in northeastern Oregon and southeastern Washington. *Northwestern Naturalist* 85:39–47.
38. *Id*.

> tions tower should be strongly encouraged to collocate the communications equipment on an existing communication tower or other structure (*e.g.,* billboard, water tower, or building mount). Depending on tower load factors, from 6 to 10 providers may collocate on an existing tower.
>
> 2. If collocation is not feasible and a new tower or towers are to be constructed, communications service **providers should be strongly encouraged to construct towers no more than 199 feet above ground level (AGL)**, using construction techniques which do not require guy wires (*e.g.,* use a lattice structure, monopole, etc.). Such towers should be unlighted if Federal Aviation Administration regulations permit.[39] [Emphasis added.]

The existing data would support the FCC adopting these recommendations as standards to better protect birds. Such standards for tower construction do not mean that towers exceeding 199 feet or any other height should not be constructed, only that the FCC would strongly encourage co-location and the construction of shorter towers to accomplish telecommunication goals while minimizing avian impacts.

4. Guyed Towers Kill More Birds Than Guyless Towers

Most towers from which large bird kills have been reported have had guy wires. Observational studies of birds in the vicinity of towers show that birds are much more likely to collide with the guy wires than with the tower itself.[40] Dr. Gehring's study in Michigan provides evidence of increased mortality caused by guyed towers compared to guyless towers of the same height and lighting regime. The Gehring study includes 12 guyed and 9 guyless communications towers 380–480 feet tall. During spring and fall 20-day survey periods in 2004, **guyed towers killed close to ten times more birds than guyless towers**.[41] This same ratio was found even after adjusting for scavenger removal and search efficiency.

It would be difficult to imagine more compelling results. Higher mortality from guyed towers would be expected because of the circling behavior exhibited by migrants under the influence of lights on towers. Furthermore, a study of bird mortality at transmission towers in Wisconsin found a high correlation between the locations of dead birds and guy wires, implicating collisions with guy wires as the cause of death.[42]

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39. Clark, J.R. 14 September 2000. Service guidance on the siting, construction, operation and decommissioning of communications towers. U.S. Fish and Wildlife Service, Washington, D.C.
40. Brewer, R., and J.A. Ellis. 1958. An analysis of migrating birds killed at a television tower in east-central Illinois, September 1955–May 1957. *Auk* 75:400–414. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291. Fisher, H.I. 1966. Midway's deadly antennae. *Audubon Magazine* 68(4):220–223.
41. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant.
42. Kruse, K. 1996. A study of the effects of transmission towers on migrating birds. M.S. thesis (Environmental Science and Policy), University of Wisconsin, Green Bay.

The hazard of guy wires to migrating birds has also been investigated by those working with wind power producers. Research on wind turbines, which are unguyed, and nearby guyed structures confirms the increased risk of guyed structures. For example, in one study, the average number of birds killed at a guyed meteorological tower was approximately three times higher than the nearby per turbine mortality. The turbines, of a similar height, are unguyed.[43]

This evidence, and the lack of records of mass bird kills at guyless towers in the reviewed literature, is sufficient for reasonable scientific minds to conclude that guy wires greatly increase mortality at towers. The evidence cited above documents the scientific merit of the U.S. Fish and Wildlife Service tower siting guidelines on the use of guy wires:

> 2. If collocation is not feasible and a new tower or towers are to be constructed, communications service providers should be strongly encouraged to construct towers no more than 199 feet above ground level (AGL), **using construction techniques which do not require guy wires (*e.g.*, use a lattice structure, monopole, etc.).** Such towers should be unlighted if Federal Aviation Administration regulations permit.
>
> 7. Towers and appendant facilities should be sited, designed and constructed so as to avoid or minimize habitat loss within and adjacent to the tower "footprint". **However, a larger tower footprint is preferable to the use of guy wires in construction.**[44] [Emphasisis added.]

The FCC could significantly reduce avian mortality at communications towers by allowing construction only of guyless towers unless applicants document that such construction is not feasible.

5. Tower Lighting Influences Bird Mortality

The lighting scheme of communications towers is probably the most important factor contributing to bird kills at towers that can be controlled by humans.[45] The current Federal Aviation Administration Advisory Circular (AC) 70/7460-1, Obstruction Marking and Lighting, dictates the use of lighting for nighttime conspicuity for aviation safety for all obstructions over 199 feet and for structures within three nautical miles of an airport. This is the only purpose in placing lights (Table 3) on communications towers and other

43. Young, D.P., Jr., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Foote Creek Rim final bird and bat mortality report: avian and bat mortality associated with the initial phase of the Foote Creek Rim Wind Power Project, Carbon County, Wyoming. November 1998–June 2002. Final Report. Western EcoSystems Technology, Inc., Cheyenne, Wyoming.
44. Clark, J.R. 14 September 2000. Service guidance on the siting, construction, operation and decommissioning of communications towers. U.S. Fish and Wildlife Service, Washington, D.C.
45. Cochran, W.W., and R.R. Graber. 1958. Attraction of nocturnal migrants by lights on a television tower. *Wilson Bulletin* 70:378–380. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.

structures — to provide for aviation safety by making sure pilots can see human-made obstructions.

Table 3. FAA-approved light types for obstruction lighting.

Type	Description
L-810	Steady-burning Red Obstruction Light
L-856	High Intensity Flashing White Obstruction Light (40 FPM)
L-857	High Intensity Flashing White Obstruction Light (60 FPM)
L-864	Flashing Red Obstruction Light (20–40 FPM)
L-865	Medium Intensity Flashing White Obstruction Light (40 FPM)
L-866	Medium Intensity Flashing White Obstruction Light (60 FPM)
L-864/L-865	Dual: Flashing Red Obstruction Light (20–40 FPM) and Medium Intensity Flashing White Obstruction Light (40 FPM)
L-885 Red Catenary	60 FPM

FPM = Flashes Per Minute

Nocturnal migrants can be attracted to lights and they are disoriented or "trapped" by the lights once within their zone of influence. This zone of influence is extended when fog is in the air reflecting the light and inclement weather or topographic factors have forced migrating birds to lower altitudes. These mechanisms have been observed not only with reference to communications towers, but also for attraction to lightships,[46] lighthouses,[47] fires,[48] oil flares,[49] ceilometers,[50] and city lights and buildings.[51]

46. Barrington, R.M. 1900. *The migration of birds as observed at Irish lighthouses and lightships*. R.H. Porter, London and Edward Ponsonby, Dublin. Bagg, A.M., and R.P. Emery. 1960. Fall migration: Northeastern maritime region. *Audubon Field Notes* 14:10–17. Dutcher, W. 1884. Bird notes from Long Island, N.Y. *Auk* 1:174–179.
47. Allen, J.A. 1880. Destruction of birds by light-houses. *Bulletin of the Nuttall Ornithological Club* 5:131–138. Brewster, W. 1886. Bird migration. Part 1. Observations on nocturnal bird flights at the light-house at Point Lepreaux, Bay of Fundy, New Brunswick. *Memoirs of the Nuttall Ornithological Club* 1:5–10. Hansen, L. 1954. Birds killed at lights in Denmark 1886–1939. *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening* 116:269–368. Lewis, H.F. 1927. Destruction of birds by lighthouses in the provinces of Ontario and Quebec. *Canadian Field-Naturalist* 41:55–58, 75–77. Miller, G.S., Jr. 1897. Winge on birds at the Danish lighthouses. *Auk* 14:415–417. Munro, J.A. 1924. A preliminary report on the destruction of birds at lighthouses on the coast of British Columbia. *Canadian Field-Naturalist* 38:141–145, 171–175. Squires, W.A., and H.E. Hanson. 1918. The destruction of birds at the lighthouses on the coast of California. *Condor* 20:6–10. Tufts, R.W. 1928. A report concerning destruction of bird life at lighthouses on the Atlantic coast. *Canadian Field-Naturalist* 42:167–172.
48. Stone, W. 1906. Some light on night migration. *Auk* 23:249–252.
49. Tornielli, A. 1951. Comportamento di migratori nei riguardi di un pozzo metanifero in fiamme [Behavior of migrants under the influence of a burning natural gas well]. *Rivista Italiana di Ornitologia* II-21:151–162. Wiese, F.K., W.A. Montevecchi, G.K. Davoren, F. Huettmann, A.W. Diamond, and J. Linke. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. *Marine Pollution Bulletin* 42:1285–1290.
50. Ferren, R.L. 1959. Mortality at the Dow Air Base ceilometer. *Maine Field Naturalist* 15:113–114. Fobes, C.B. 1956. Bird destruction at ceilometer light beam. *Maine Field Naturalist* 12:93–95. Howell,

Historical accounts suggest that, at least for birds attracted to lighthouses, solid white lights are more attractive to birds than colored or flashing lights. Barrington analyzed birds that were killed at 58 lighthouses and concluded that solid lights were more attractive to migrants than blinking lights and that white lights were more attractive than red lights.[52] Others concluded that, "fixed white lights were more deadly than revolving or coloured lights"[53] and that, "coloured lights do not attract the birds as white ones so fatally do."[54] Although colored (red) lights at lighthouses may have attracted fewer birds, flashing red and solid red lights in combination on communications towers are well documented to attract birds, especially night-flying migrants.[55] Conclusive evidence is not available that the color of light affects bird attraction, and Verheijen concludes that lesser attraction at colored lights is a function of their generally lower intensity.[56] Nevertheless, birds are attracted to red obstruction lighting, even if the lighting may be classified as low intensity. The role of color is confounded with the duration of the light — evidence indicates that white and probably red strobe-type lights are less attractive to birds than solid light of either color, as discussed below.

It should be noted that attraction of birds to white light does not mean that white strobes will also be attractive for birds as suggested by comments from the communications industry.[57] The unpublished research cited by the communications industry is described by Kerlinger[58] as documenting attraction of birds to solid white light over colored light, constant light over flashing light, and light over darkness in a captive, experimental setting. The report of this study does not indicate that strobe lights were tested and other details of the study are not available, and therefore it should not be assumed that it provides evidence that white strobes would be attractive to migrating birds.

Observation of bird behavior at towers lighted with solid red (L-810) and flashing red (incandescent L-864) lights confirms that light is the stimulus that keeps birds circling the tower and thereby substantially increasing risk of mortality. Cochran and Graber ob-

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J.C., A.R. Laskey, and J.T. Tanner. 1954. Bird mortality at airport ceilometers. *Wilson Bulletin* 66:207–215.

51. Gastman, E.A. 1886. Birds killed by electric light towers at Decatur, Ill. *American Naturalist* 20:981. Overing, R. 1938. High mortality at the Washington Monument. *Auk* 55:679. Lord, W.G. 1951. Bird fatalities at Bluff's Lodge on the Blue Ridge Parkway, Wilkes County, N.C. *Chat* 15:15–16.
52. Barrington, R.M. 1900. *The migration of birds as observed at Irish lighthouses and lightships*. R.H. Porter, London and Edward Ponsonby, Dublin.
53. Dixon, C. 1897. *The migration of birds: an attempt to reduce avine season-flight to law*. Windsor House, London.
54. Thomson, A.L. 1926. *Problems of bird-migration*. H.F. & G. Witherby, London.
55. Weir, R.D. 1976. *Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions*. Department of Fisheries and the Environment, Environmental Management Service, Canadian Wildlife Service, Ontario Region, Ottawa.
56. Verheijen, F.J. 1985. Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. *Experimental Biology* 44:1–18.
57. Avatar Report, p. 3-49.
58. Unpublished research described in Kerlinger, P. 2002. *Avian mortality at communication towers: a review of recent literature, research, and methodology*. Report to U.S. Fish and Wildlife Service, Office of Migratory Bird Management.

served birds flying around incandescent red lights on a tower. When the lights were switched off, the birds dispersed. Birds congregated anew when the lights were switched back on.[59] Avery et al. repeated this experiment, and birds dispersed when the lights were extinguished.[60] As others have noted, "Avery's data suggest that the tower's obstruction lights were the <u>sole</u> factor in the congregation of birds."[61] Larkin and Frase also documented the circular flight paths of birds around a broadcast tower lighted with solid red and flashing red lights.[62] The Avatar Report does not adequately convey the certainty of this information or the central importance of lights in causing birds to collide with towers. The combination of solid red and flashing red lights (L-810 with incandescent L-864) attracts and disorients birds, which accumulate around towers, collide with each other, the tower, guy wires, and the ground, die of exhaustion, or deplete their fat reserves.

5.1. Disorientation by Red Lights Has Physiological Basis

The accumulation of birds near red lights may result from the same mechanism that attracts birds to white lights, from disruption of magnetic orientation under red wavelengths, or from a combination of both mechanisms. Nocturnal migrants are attracted to both red and white lights, become "trapped" in the lighted area, and do not return to the darkness of their migratory path. This has been shown in experiments where birds, varying by species and individual, move into lighted areas but not back into dark ones.[63]

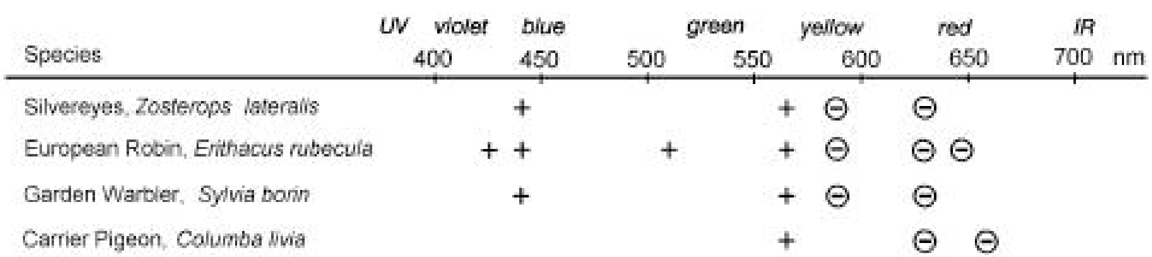

Figure 4. Orientation (+) and disorientation (–) responses of birds under different wavelengths.[64]

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59. Cochran, W.W., and R.R. Graber. 1958. Attraction of nocturnal migrants by lights on a television tower. *Wilson Bulletin* 70:378–380.
60. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.
61. Weir, R.D. 1976. *Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions*. Department of Fisheries and the Environment, Environmental Management Service, Canadian Wildlife Service, Ontario Region, Ottawa, p. 18.
62. Larkin, R.P. and B.A. Frase. 1988. Circular paths of birds flying near a broadcasting tower in cloud. *Journal of Comparative Psychology* 102:90–93.
63. Verheijen, F.J. 1958. The mechanisms of the trapping effect of artificial light sources upon animals. *Archives Néerlandaises de Zoologie* 13:1–107.
64. Wiltschko, W., and R. Wiltschko. 2002. Magnetic compass orientation in birds and its physiological basis. *Naturwissenschaften* 89:445–452.

The evidence for disruption of magnetic orientation by red light is strong. Birds, when denied celestial cues, use magnetic orientation to guide migration direction.[65] It has been demonstrated in birds of several families that this magnetic orientation depends on the presence of light less than 590 nm (yellow; Figure 4). This magnetic orientation is disrupted under yellow and red light, as shown for European Robin (Figure 5). Birds within the visual sphere of influence of a red light would be denied use of celestial cues by the glare of the lights, and often by inclement weather that extends the influence of the lights. In this situation, the birds would also be denied use of magnetic orientation because of the absence of shorter wavelengths necessary for magnetic orientation to function, which may lead to disorientation and circular flight in the vicinity of the lights.[66]

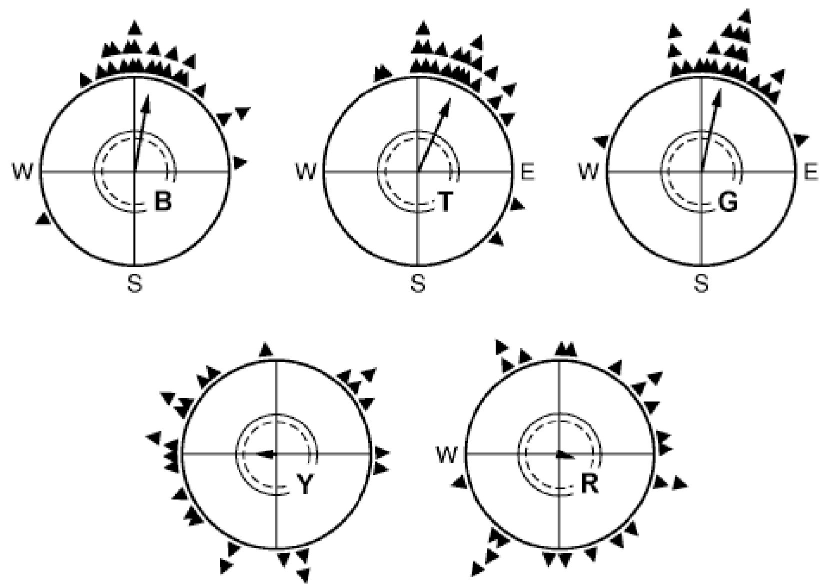

Figure 5. Orientation of European Robins under low-intensity light of different wavelengths in the spring. Birds under blue (B, 424 nm), turquoise (T, 510 nm), and green light (G, 565 nm) oriented properly, as indicated by the arrow in the circle. Individuals under yellow (Y, 590 nm) and red (R, 635 nm) light did not orient correctly.[67]

65. Deutschlander, M.E., J.B. Phillips, and S.C. Borland. 1999. The case for light-dependent magnetic orientation in animals. *Journal of Experimental Biology* 202:891–908. The evidence for magnetic orientation in birds is derived from studies of birds before flight, choosing a migratory direction. Definitive evidence of use of the magnetic compass during flight has not been obtained.
66. Gauthreaux, S.A., Jr., and C. Belser. 2005. Effects of artificial night lighting on migrating birds. *In* C. Rich and T. Longcore (eds.), *Ecological consequences of artificial night lighting*. Island Press, Covelo, California.
67. Wiltschko, W., and R. Wiltschko. 2002. Magnetic compass orientation in birds and its physiological basis. *Naturwissenschaften* 89:445–452.

5.2. White Strobe Lighting Does Not Attract, or Negligibly Attracts, Migratory Birds

Duration of lighting is critical to whether birds are or are not attracted to lights. The Avatar Report states that, "Although some studies and several anecdotal reports suggest that white strobe lights may be less attractive to birds, this has not been proven to date."[68] This conclusion improperly downplays the strength of the evidence that white strobe lights do not attract migrating birds, perhaps because the Avatar Report does not include studies from other lighted structures such as lighthouses.

The Dungeness Lighthouse in Kent, England was well known for chronic bird kills. In 1961, its revolving beam was replaced with a bluish-white lamp that flashed one second in every ten seconds. The Warden of the Dungeness Bird Observatory noted:

> An intermittent, flashing light (i.e. as the new Dungeness light) proves of no attraction to birds and casualties have never been found…. So we see that a lighthouse long known to kill large numbers of night migrants in a manner familiar to any who have witnessed kills, has *ceased* to kill any simply by changing its old 10-beam revolving light for a flashing light sending the same signal.[69]

Observations during the transition week between lights, under similar weather conditions, showed bird attraction with the constant revolving light, but none with the intermittent light.[70]

The historical record of bird mortality at lighthouses with incandescent flashing (**not** strobe) lights is mixed. Some lighthouse keepers reported hundreds of mortalities annually, while others reported none.[71] This record is difficult to interpret because the literature does not describe the lights well. None of the lighthouses described in these early studies was equipped with strobe lights, which had not yet been invented.[72]

All reports indicate that replacement of solid lights with white strobe lights (and no other lights) reduces bird kills. When stacks and towers at a power plant in Canada were equipped with strobe lights, bird kills were "virtually eliminated."[73] Some U.S. television towers were equipped with white strobe lights (e.g., L-865) instead of solid red (L-810) and flashing red (L-864) for the first time in 1973.[74] Although 11 of the one-night kills

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68. Avatar Report, p. 3-43.
69. T.E. Scott, quoted in Baldwin, D.H. 1965. Enquiry into the mass mortality of nocturnal migrants in Ontario: final report. *Ontario Naturalist* 3:3–11.
70. Baldwin, D.H. 1965. Enquiry into the mass mortality of nocturnal migrants in Ontario: final report. *Ontario Naturalist* 3:3–11, p. 10.
71. Lewis, H.F. 1927. Destruction of birds by lighthouses in the provinces of Ontario and Quebec. *Canadian Field-Naturalist* 41:55–58, 75–77.
72. Strobe lights were invented in the 1930s.
73. Ogden, L.J.E. 1996. *Collision course: the hazards of lighted structures and windows to migrating birds*. World Wildlife Fund Canada and the Fatal Light Awareness Program, Toronto, Canada, p. 29.
74. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291, p. 289.

reported in the literature occurred since 1973, none was at a tower with only strobe lights.[75]

Gauthreaux and Belser investigated the influence of light type on bird behavior around towers. The complete details of the Gauthreaux and Belser study were not available to Avatar Environmental for its review. This study has been peer-reviewed as part of a chapter to be published in a forthcoming edited book.[76] It provides additional scientific evidence that white strobe lights do not attract birds to towers and that strobe lights affect bird behavior less than solid red and flashing incandescent red lights when birds are in the vicinity of a tower.

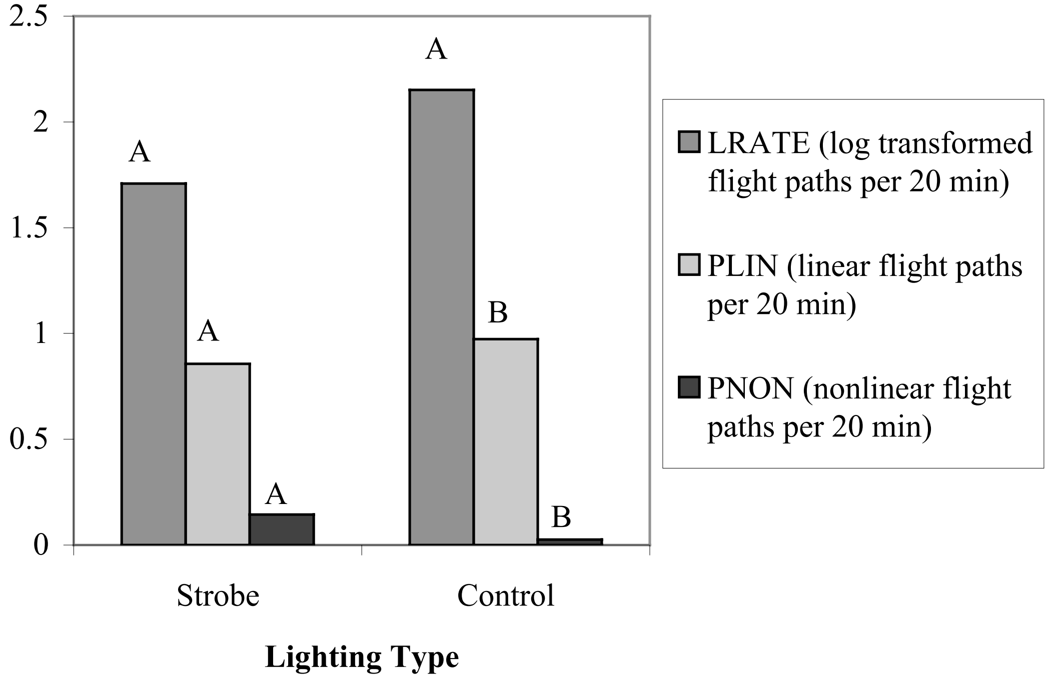

Figure 6. Rate, linear, and nonlinear migratory bird flights around control and strobe-lit tower sites at Neese, Georgia. Rate of linear and nonlinear paths are significantly different, with more nonlinear flights around the strobe-lit tower. The average rate of birds flying at each location was not significantly different.

Gauthreaux and Belser recorded bird behavior at towers at two study sites. At a site near Neese, Georgia, they compared bird flights at a 1,200-foot television tower with white

75. See reports reviewed in Woodlot Report. We consider the mass kill of Lapland Longspurs at a strobe-lighted tower to be a special event, likely explained by attraction to lighted facilities near the tower, an opinion that is shared by many experts. See Eaton, J. 2003. Tower kill. *Earth Island Journal* 17(4):32–35.
76. Gauthreaux, S.A., Jr., and C. Belser. 2005. Effects of artificial night lighting on migrating birds. *In* C. Rich and T. Longcore (eds.), *Ecological consequences of artificial night lighting*. Island Press, Covelo, California.

strobe lights (40–46 pulses per minute; L-856 or L-865) and a control site. Linear, nonlinear, and total paths were recorded and analyzed using general linear models with date and tower type (location) as explanatory variables. Results (Figure 6) show statistically significant higher rates of nonlinear flight around the strobe-lit tower compared to the control (no towers with red lights were studied in Georgia), but not significantly more total birds at the tower with white strobe lights compared with the control. The Avatar Report characterization that "white strobe lights attracted birds as compared to unlit control sites that attracted none"[77] is not accurate for the study as accepted for publication — there was **no significant difference between the number of bird flight paths at the control site and at the tower with white strobes**.

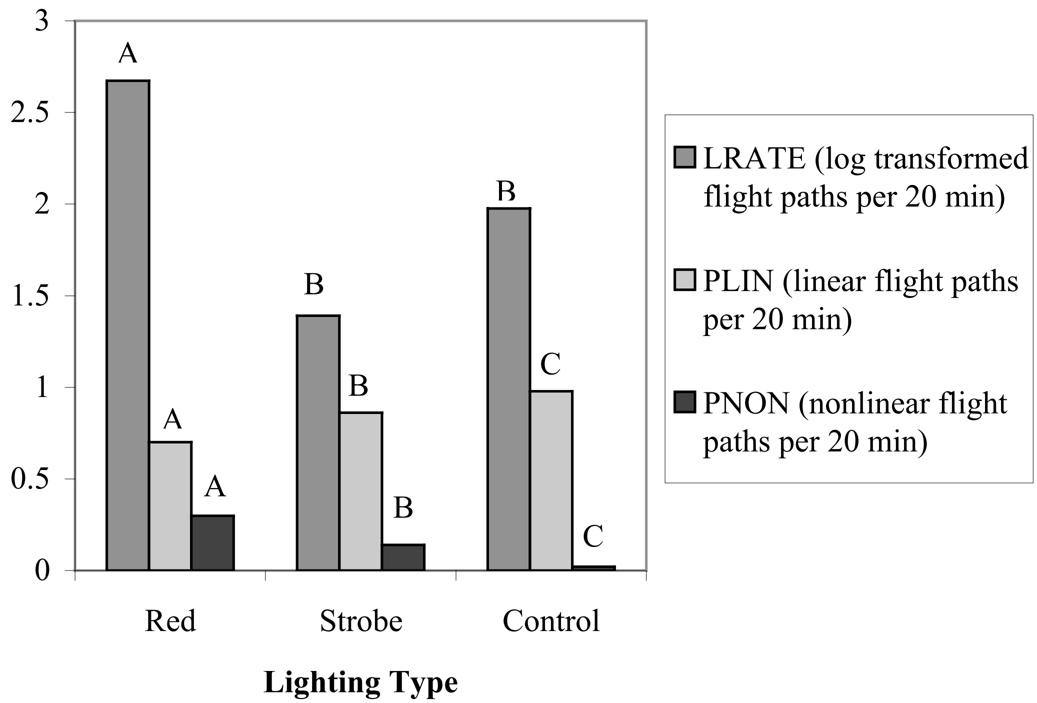

Figure 7. Rate, linear, and nonlinear migratory bird flights around towers with 1) a combination of solid red and flashing incandescent red lights, 2) white strobe lights, and 3) a control site without a tower near Moores Landing, South Carolina. Letters indicate statistically significant differences.

The second part of the study was conducted near Moores Landing, South Carolina during the fall migration. Gauthreaux and Belser monitor bird flights on 14 nights at two towers, one tower (1,667 feet) with incandescent flashing red and solid red lights (L-810) and one tower (2,016 feet) with white strobe lights, and a nearby control site. General linear models revealed that the number of flights was influenced by the day of observation and tower type. Significantly more birds were observed at the tower with the combination of

77. Avatar Report, p. 3-48.

red lights than at the tower with white strobe lights or the control site. Furthermore, lighting type was significantly associated with number of nonlinear flight paths, with twice as many nonlinear flight paths at the tower with red lights than at the tower with white strobe lights on average, and nearly **14 times more nonlinear flight paths at the red lighted tower than at the control sit**e.

The results suggest that although white strobe lights cause birds to take more nonlinear flight paths, they do not result in birds accumulating around the tower. Gauthreaux and Belser conclude that the significantly greater number of paths per 20 minutes around the tower with red lights resulted from the attraction of the lights, added to the influence of the lights on orientation, leading to accumulations of individuals near the towers with solid red and flashing red lights.[78]

Contrary to the characterization in the Avatar Report, the scientific evidence, including a study at two locations, indicates that white strobe lights on towers result in less bird attraction than red (solid and flashing incandescent) lights and, by extension, lower bird mortality. Indeed, the use of strobe lights has been recommended by a series of researchers investigating this topic. Verheijen, who wrote the classic review on the attraction of animals to light,[79] concludes that, "Success has been achieved in the protection of nocturnal migrant birds through interrupting the trapping stimulus situation by … replacing the stationary warning lights on tall obstacles by lights of strobe or flashing type."[80] Jones et al. similarly conclude that strobe lights with a complete break between flashes would reduce bird mortality at tall structures.[81]

Dr. W. Taylor, Professor Emeritus of Biology at Central Florida University, reports drastic reduction of bird mortality when lighting of a tower in Orlando, Florida was changed from solid red and flashing red lights to white strobe lights (pers. comm.). The tower was the site of large bird kills, and Professor Taylor and colleagues had collected more than 10,000 birds over the years and reported these kills in the literature.[82] In 1974, the ~1,000-foot guyed tower blew down, and was replaced with a taller guyed tower with white strobe lights. Following the replacement, bird mortality was reduced drastically and no mass kills (i.e., >100 birds) were ever again reported at the site.

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78. See also Graber, R.R., and W.W. Cochran. 1960. Evaluation of an aural record of nocturnal migration. *Wilson Bulletin* 72:253–273. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.
79. Verheijen, F.J. 1958. The mechanisms of the trapping effect of artificial light sources upon animals. *Archives Néerlandaises de Zoologie* 13:1–107.
80. Verheijen, F.J. 1985. Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. *Experimental Biology* 44:1–18.
81. Jones, J., and C.M. Francis. 2003. The effects of light characteristics on avian mortality at lighthouses. *Journal of Avian Biology* 34:328–333.
82. Taylor, W.K., and B.H. Anderson. 1973. Nocturnal migrants killed at a south central Florida TV tower, autumn 1969-1971. *Wilson Bulletin* 85:42–51. Taylor, W.K., and B.H. Anderson. 1974. Nocturnal migrants killed at a south central Florida TV tower, autumn 1972. *Florida Field Naturalist* 2:40–43.

Two television towers near Awendaw, South Carolina had substantial bird kills during the 1980s when they had red incandescent lighting. The towers were changed to white strobe lights in about 1990 and few dead birds have been found around them since.[83]

An average of 2,300 birds per year were killed over a 10-year period at lighted smoke-stacks near Kingston, Ontario. After the lights were changed to white strobes, the bird kills ended.[84]

The observation that strobe-type lights (L-864 red strobes) do not attract night migrating birds has been made by those analyzing bird kills at wind turbines as well.[85] No comparison of attraction of birds to red strobes versus white strobes on communications towers is available because solid red lights (L-810) are always on towers along with red strobe lights. Many researchers believe that it is unlikely that red or white strobes attract birds at night.

Reports such as those from Florida, South Carolina, and Ontario are likely to be characterized as anecdotal and afforded less weight than peer-reviewed studies. But to ignore the many accounts of bird kills being virtually eliminated by changing to white strobe lights would be scientifically unsound. Anecdotal observations are data. Although they may not be accompanied by precise quantification, precision is not necessary when effects are large. For example, the dataset for the Orlando tower described by Dr. Taylor was well over 100 birds per year before the change to strobe lighting, then well under 100 birds per year following the change to strobe lighting. Even without knowing the exact number of years of observation before or after the change in light type, or the exact number of birds beyond those classes (i.e., over 100 birds/under 100 birds per year), one can conclude with a high degree of statistical certainty that the magnitude of mortality was significantly different. Absent another rational explanation for this difference (e.g., removal of guy wires, decrease in height, drastic change in weather), the only defensible scientific conclusion is that the changed lighting scheme was responsible for the difference. Furthermore, this same observation has been made on multiple occasions at different locations. It is possible, logical, and scientific to draw conclusions from multiple observations of the same phenomenon, even if those observations are not part of a pre-arranged scientific design. Multiple, consistent observations of the same response can be adequate to draw a statistically valid conclusion, so long as the effect size is sufficiently large.

To disprove the conclusion that bird kills are lower at strobe-lighted towers, many tall towers equipped with strobe lights would have to have been the site of large bird mortality events and NOT have been reported or noticed by anyone. The one reported instance

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83. Dr. W. Post, Curator of Birds, The Charleston Museum, pers. comm. to G. Winegrad.
84. Broderick, B. 1995. Light waves: why be concerned about light pollution? *Royal Astronomical Society of Canada Bulletin* 5(3):6.
85. See Kerlinger, P. 2004. Attraction of night migrating birds to FAA and other types of lights. Curry & Kerlinger, LLC, Cape May, New Jersey.

of mass mortality at a strobe-lighted tower was an "abnormality"[86] confounded by the presence of other lighting at the site.

The Avatar Report concludes that the existing research is insufficient to make recommendations about lighting at communications towers. This conclusion is not accurate after considering the weight of the evidence, including the details of the Gauthreaux and Belser study that were not available to Avatar Environmental. Every known instance of changing to strobe lights at towers has reduced bird mortality and this solution has been known and recommended for 40 years. Reducing the attraction of birds to towers is a critical factor in minimizing bird deaths at towers. Without attraction, birds may still encounter and be killed in collisions with towers that are sited in migratory pathways, but the sum of the available scientific evidence indicates that mortality would be greatly reduced by using only strobe lights at towers.

The evidence above supports the U.S. Fish and Wildlife Service tower siting guidelines, which provide:

> 2. If collocation is not feasible and a new tower or towers are to be constructed, communications service providers should be strongly encouraged to construct towers no more than 199 feet above ground level (AGL), using construction techniques which do not require guy wires (*e.g.,* use a lattice structure, monopole, etc.). **Such towers should be unlighted if Federal Aviation Administration regulations permit**….
>
> 5. If taller (>199 feet AGL) towers requiring lights for aviation safety must be constructed, the minimum amount of pilot warning and obstruction avoidance lighting required by the FAA should be used. **Unless otherwise required by the FAA, only white (preferable) or red strobe lights should be used at night, and these should be the minimum number, minimum intensity, and minimum number of flashes per minute (longest duration between flashes) allowable by the FAA. The use of solid red or pulsating red warning lights at night should be avoided. Current research indicates that solid or pulsating (beacon) red lights attract night-migrating birds at a much higher rate than white strobe lights. Red strobe lights have not yet been studied.**[87] [Emphasisis added.]

The research and studies cited and discussed above supports the U.S. Fish and Wildlife Service Guidelines for keeping towers unlit or lit exclusively with white or red strobes to minimize avian mortality. The FAA apparently concurs and has recommended the use of white strobes.

To reduce avian mortality, it is also important that accessory structures at towers, especially shorter unlit towers, not have constant exterior lighting. Studies from bird kills at

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86. Woodlot Report, p. 22.
87. Clark, J.R. 14 September 2000. Service guidance on the siting, construction, operation and decommissioning of communications towers. U.S. Fish and Wildlife Service, Washington, D.C.

wind turbines reveal greater kills at turbines near lighted structures.[88] Avoidance of lights on accessory structures for towers in natural areas would also reduce adverse effects on other taxa.[89]

6. Topography Influences Bird Mortality at Towers

Topography is known to concentrate migrants in certain locations such as coastlines, mountain ridges, rivers, and hills. Considerable evidence of this effect has been gathered in Europe,[90] with somewhat fewer studies in North America. A recent multi-modal research study in New Hampshire revealed the effect of the topography of the Appalachian Mountains on migratory birds, including neotropical migrants traversing southeast over the chain toward wintering grounds in Central and South America. At two ridgeline sites, the researchers observed "exceptional numbers of migrants at 2 to 30 m AGL [Above Ground Level]."[91] They conclude, consistent with the European studies, that it should not be assumed that birds migrate in a broad front across mountains. They continue:

> [This] is important for evaluation of structures such as wind-powered electrical generators or communication towers on ridge lines. Although our studies were not designed to observe concentrations of migrants at topographical features, reaction of migrants to topography that we did observe suggested such concentrations during both favorable and unfavorable conditions. Concentrations could result either as birds moved along a corridor, such as a pass or ridge line, or they could result from birds moving up and over a ridge meeting migrants already at that altitude and thus producing large numbers of birds a few tens of meters above the ridge summit. Our ceilometer observations of large numbers of birds near crests of ridges are particularly relevant in that regard.[92]

This study, which is plainly relevant but not cited in the Avatar Report, provides convincing peer-reviewed evidence that the placement of communications towers along ridgelines is likely to result in increased bird mortality than placement elsewhere. It pro-

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88. See Kerlinger, P. 2004. Attraction of night migrating birds to FAA and other types of lights. Curry & Kerlinger, LLC, Cape May, New Jersey.
89. Longcore, T., and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2:191–198.
90. Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* 118:389–403, citing Bruderer, B. 1978. Effects of alpine topography and winds on migrating birds. Pp. 252–265 *in* K. Schmidt-Koenig and W. Keeton (eds.), *Animal migration, navigation, and homing*. Springer-Verlag, Berlin. Bruderer, B. 1999. Three decades of tracking radar studies on bird migration in Europe and the Middle East. Pp. 107–141 *in* Y. Leshem, Y. Mandelik, and J. Shamoun-Baranes (eds.), *Proceedings international seminar on birds and flight safety in the Middle East*. Tel-Aviv, Israel. Bruderer, B., and L. Jenni. 1988. Strategies of bird migration in the area of the Alps. Pp. 2150–2161 *in* H. Ouellet (ed.), *Acta XIX Congressus Internationalis Ornitologici*. National Museum of Natural Science, Ottawa, Ontario. Eastwood, E. 1967. *Radar ornithology*. Methuen, London.
91. Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* 118:389–403, p. 394.
92. Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* 118:389–403, p. 401.

vides a rational explanation for why some short towers cause high bird mortality (e.g., a kill at a 100-foot unlighted tower on a ridgeline). Birds will be killed at a tower whenever large numbers are flying near it at the same elevation as the tower. This can occur because the tower is tall or because it is placed topographically where birds are concentrated close to the ground. At ridgeline locations, inclement weather is not required for concentrations of birds to be found at low elevation. Radar studies can be conducted prior to siting a tower in an area that might concentrate night migrants so that the tower can be located to avoid such sites.

7. Data Quality Act

The communications industry appears eager to use the Data Quality Act and its implementation by the FCC as a way to discount the available information about bird mortality at communications towers. The National Association of Broadcasters et al. asserts, "As described in more detail in the attached Technical Comments, most reports, observations and studies on the supposed effects of communications towers on migratory birds have not been peer-reviewed and would not qualify as 'quality information' under the Commission's own DQA Information Quality Guidelines."[93] In their commissioned report, Woodlot Alternatives writes:

> Most of the literature cited, particularly those involving observations and incidental reports, was found to be of limited scientific value. Referring to some aspects of the FCC's Data Quality guidelines (transparency and reproducibility), we used these criteria to assess the 27 peer-reviewed studies used in this review. In accordance with these guidelines, published papers were required to 1) have a research protocol with a clearly described methods section; 2) maintain sufficient metrics for statistical analyses; 3) have clearly stated results; and 4) have reproducible results. The studies that appeared to meet these criteria were published in peer-reviewed scientific journals. We found that 19 studies met the above criteria as discussed in the guidelines and 8 studies were doubtful in this regard (Table 4). None of the 173 incidental reports of avian mortality met the FCC Data Quality guidelines for transparency and reproducibility.

The eagerness to characterize incidental reports of bird mortality at particular towers as "of limited scientific value" misses the point. Incidental observations are neither useless nor ideal for scientific inquiry. Their appropriateness for use depends upon the purpose to which they are put. As long as assumptions are made explicit, incidental observations can be used to develop a description of reality using the scientific method.

While the communications industry concentrates on the elements of "reproducibility" and "transparency," it does not discuss the need for analysis to be objective. In the FCC's implementing guidelines, this means that if alternative explanations for patterns in data exist, they should be included in any discussion of results.[94] Both the Woodlot Report

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93. CITIA/NAB Comments, p. 28 (footnote omitted).
94. The Information Quality Guidelines (FCC 02-277) read, in part: "Objectivity will be demonstrated by including in the information dissemination product's methodology section or appendix a discussion of

and the Avatar Report fail to do this. Many of the conclusions presented above are alternative, and we believe more accurate, interpretations of the material presented in the Avatar Report. The Avatar Report avoids drawing obvious inferences from the available data to such a degree that it could be interpreted as lacking objectivity. For example, it claims that little research on bird mortalities at towers has been completed in the past twenty years,[95] despite many recent studies available to Avatar.[96]

8. Conclusion

Our review of the scientific literature, combined with our analysis conducted in the preparation of this report, and the unpublished and in-press research described above, leads us to the conclusion that sufficient reliable information is available to implement communications tower guidelines that would reduce existing and future significant adverse impacts on bird populations. Many research needs are apparent — evaluating the attractiveness of strobe-type flashing red lights without the confounding effect of solid red lights and testing the hypothesis that red light disorients birds while in flight by disrupting their magnetic compass are only two. We conclude, however, that the U.S. Fish and Wildlife Service tower siting guidelines have a strong scientific basis, and their applicability has been demonstrated by research available at the time they were issued in 2000, or completed since then.

In view of the significant adverse effects on bird populations if nothing is done, an adaptive management approach would be advisable.[97] Adaptive management allows for a management action to be taken, such as requiring only strobe-type lights on new towers, while continuing to increase scientific knowledge by studying the effects of such actions (e.g., monitoring and comparing bird mortality at towers with all white strobe lights, all red strobe lights, and mixed solid red and red strobe lights on towers). Future recommendations can be modified to incorporate the findings of such studies. Many alternative

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other scientifically, financially, or statistically responsible and reliable alternative views and perspectives, if these alternative views or perspectives are not already noted in other sections of the information dissemination product."

95. Avatar Report, p. 3-1.
96. Morris, S.R., A.R. Clark, L.H. Bhatti, and J.L. Glasgow. 2003. Television tower mortality of migrant birds in western New York and Youngtown, Ohio. *Northeastern Naturalist* 10:67–76. Nehring, J., and S. Bivens. 1999. A study of bird mortality at Nashville's WSMV television tower. *Migrant* 70:1–8. Kemper, C.A. 1996. A study of bird mortality at a central Wisconsin TV tower from 1957–1995. *Passenger Pigeon* 58:219–235. Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388. Kruse, K. 1996. A study of the effects of transmission towers on migrating birds. M.S. thesis (Environmental Science and Policy), University of Wisconsin, Green Bay. Ball, L.G., K. Zyskowski, and G. Escalona-Segura. 1995. Recent bird mortality at a Topeka television tower. *Kansas Ornithological Bulletin* 46(4):33–36. Larkin, R.P., and B.A. Frase. 1988. Circular paths of birds flying near a broadcasting tower in cloud. *Journal of Comparative Psychology* 102:90–93.
97. Holling, C.S. 1978. *Adaptive environmental assessment and management*. New York: John Wiley & Sons. Walters, C.J. 1986. *Adaptive management of renewable resources*. New York: MacMillan Press. Haney, A., and R.L. Power. 1996. Adaptive management for sound ecosystem management. *Environmental Management* 20:879–886.

mitigation strategies could be investigated and eventually adopted under an adaptive management approach (e.g, different lighting colors, different flash rates), but progress in reducing current adverse impacts and minimizing future impacts from communications towers requires immediate action based on the substantial existing research.

9. About the Authors

Dr. Travis Longcore and Catherine Rich are co-editors of the forthcoming book *Ecological Consequences of Artificial Night Lighting* (Island Press). They provide expert comments on environmental impact analysis documents, concentrating on presenting a thorough review of the scientific literature. Dr. Longcore is Research Assistant Professor of Geography at the University of Southern California Center for Sustainable Cities and Lecturer for the UCLA Department of Ecology and Evolutionary Biology and the UCLA Institute of the Environment. He was graduated *summa cum laude* from the University of Delaware with an Honors B.A. in Geography, and holds an M.A. and a Ph.D. in Geography from UCLA. Ms. Rich holds an A.B. with honors from the University of California at Berkeley, a J.D. from the UCLA School of Law, and an M.A. in Geography from UCLA. She is a licensed attorney in California (currently on inactive status), and is Executive Officer of The Urban Wildlands Group, a conservation non-profit that she co-founded with Dr. Longcore. Dr. Sidney A. Gauthreaux, Jr. has studied behavioral and physiological aspects of bird migration since the late 1950s. He is currently Professor of Biological Sciences at Clemson University and Director of the Clemson University Radar Ornithology Laboratory.

Dr. C. Zonneveld (Free University, Amsterdam) provided useful criticism of the statistical analysis. All errors and omissions remain the responsibility of the authors.

10. Appendix: Data Used in Analysis of Tower Height

To allow transparency and reproducibility of the analysis of tower height presented in Section 3, the dataset is provided here. These data were obtained from, and full citations are found in, the Woodlot Report and a report from the National Wind Coordinating Committee.[98]

Table 4. Studies of birds killed at towers providing estimates of mean annual mortality.

Source	State	Tower Height (feet)	Duration of Study (years)	Mean Annual Mortality
C. Nicholson, pers. comm. [99]	TN	197	3	8
Seets and Bohlen 1977	IL	605	1	206
Young et al. 1994	KS	653	0.5	1,272
Young et al. 1994	KS	700	0.5	1,080
Bierly 1968, 1969, 1972, Remy 1974, 1975, Cooley 1977	AL	825	4	82
Morris et al. 2003	NY	961	30	267
Seets and Bohlen 1977	IL	981	0.5	130
Kemper 1996	WI	1,000	38	250
Crawford and Engstrom 2001	FL	1,010	29	1,517
Seets and Bohlen 1977	IL	1,047	0.5	1,176
Morris et al. 2003	NY	1,059	30	35
Seets and Bohlen 1977	IL	1,063	0.5	969
Morris et al. 2003	NY	1,076	30	370
Young et al. 1994	KS	1,079	0.5	912
Morris et al. 2003	OH	1,084	18	144
Young et al. 1994	KS	1,154	0.5	672
Carter and Parnell 1976	NC	1,188	2	767
Avery et al 1976	ND	1,197	3	1,075
Young et al. 1994	KS	1,253	0.5	408
Stmad 1975	MN	1,314	5	701
Seets and Bohlen 1977	IL	1,338	0.5	942
Nehring and Bivens 1999	TN	1,364	38	523
Seets and Bohlen 1977	IL	1,458	0.5	1,680
Taylor and Anderson 1973	FL	1,481	3	2,594
Seets and Bohlen 1977	IL	1,587	0.5	326
Carter and Parnell 1976	NC	1,994	2	767

98. Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young, Jr., K.J. Sernka, and R.E. Good. 2001. *Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States*. National Wind Coordinating Committee (NWCC) Resource Document.
99. C.P. Nicholson, Ph.D., Tennessee Valley Authority, pers. comm. to G. Winegrad, March 26, 2004.

Table 5. Results of logistic regression of annual mortality class by tower height.

Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	3.723222	1	7.446445	0.0064
Full	10.322085			
Reduced	14.045308			

RSquare (U)	0.2651
Observations (or Sum Wgts)	26

Converged by Gradient

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-3.7233453	2.3306353	2.55	0.1101
Tower Height	0.00489571	0.0023436	4.36	0.0367

For log odds of over 250/under 250

Table 6. Results of logistic regression of annual mortality class by tower height omitting the only short, unlit tower.

Whole Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	2.257167	1	4.514335	0.0336
Full	10.252893			
Reduced	12.510061			

RSquare (U)	0.1804
Observations (or Sum Wgts)	25

Converged by Gradient

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-3.4047111	2.5411879	1.80	0.1803
Tower Height	0.00458966	0.0025254	3.30	0.0692

For log odds of over 250/under 250